Enterprise Location Decisions and the Pollution Haven Hypothesis

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Abstract

In this paper I evaluate theoretically and empirically the *Pollution Haven Hypothesis* which states that enterprises will locate production in countries where environmental standards are less strict. Although the subject of multiple studies in the last two decades, empirical evidence is so far inconclusive. I begin by developing a model of international trade and investment that highlights the role of pollution and environmental standards in enterprise production location decisions. The model shows that country environmental standards impact the tradeoff between trade and foreign direct investment (FDI) resulting in enterprises locating production where environmental standards are the least strict. I confront the model empirically with data and find evidence of the existence of a systematic pollution haven effect across all countries and development levels. Most notably, the results indicate a strong pollution haven effect among developing countries with regard to the enforcement of environmental regulations.

Keywords: Pollution Haven Hypothesis, Environmental Policy, International Trade, Foreign Direct Investment, Development

[1] I am grateful to Antoine Gervais for his knowledge and guidance over the past year as my advisor. This paper would not have been possible without his assistance.

1. Introduction

The *pollution haven hypothesis* (PHH) states that less-stringent country environmental standards create a comparative advantage in the production processes of industrial enterprises. More lenient environmental regulations and enforcement lower the costs of production across industries, and this effect is especially pronounced in highly-polluting industries (Taylor 2004). International mobility of production should therefore result in the movement of pollution-intensive industry to the environmentally-lax countries or 'pollution havens' (Kheder and Zugravu 2008). If this hypothesis is correct, countries – especially developing nations – would face an incentive to enable more pollution and greater damage to their natural environments in order to promote the industrialized economic development brought by inward foreign direct investment (FDI). What is the impact of environmental protection on the enterprise production location decision? The answer to this question has critical implications for the future of international environmental cooperation and sustainability.

Beyond the consequential environmental destruction, such state behavior is harmful to the health of its citizens, and especially culturally devastating to local/indigenous populations who have strong ties to their natural environments. The increase in trade/capital liberalization in the modern, global economy resulting from international agreements like NAFTA and the WTO would serve to exasperate these concerns. Additionally, the effectiveness of international environmental treaties is subject to enterprise relocation because, if mobility is responsive to environmental standards, environmentally destructive industries could simply relocate to non-member countries – raising the already high level of international cooperation needed to address environmental destruction and climate change to even greater heights.

Although the existing literature on the topic represents many attempts at providing an answer to the question raised by the PHH, no empirical consensus has yet been reached[2]. Previous studies have

[2] The originally proposed pollution haven hypothesis measured the economic flow of goods production following an opening to trade and capital mobility (See: Copeland and Taylor (1994)). However, given the empirical difficulty

suffered from a few key omissions that may be a factor in creating the observed variance in research conclusions. Specifically, these studies: largely do not base the empirical estimations in theoretical foundations, either observe trade flows or FDI individually and thus provide incomplete assessments of enterprise location choice, do not utilize widespread bilateral trade/investment data and therefore extrapolate conclusions from the trade/investment flows of only a specific region or group of countries, and mostly do not use proper datasets that assess regulatory stringency and enforcement – opting instead to construct biased proxies. This study contributes to the literature by addressing each of these concerns in turn.

The first contribution of this paper is the application of an economic theoretical model to the PHH by means of extending a common gravity model framework of international trade and investment in order to include a role for environmental regulatory strength. In order to test the basis of the PHH, I adopt a form of the model of production location with heterogeneous enterprises described by Helpman, Melitz, and Yeaple (2004) as well as Brainard (1993) and observe the bilateral ratio of exports to FDI (domestic versus foreign production) for pairs of countries in order to include in the assessment both ways an enterprise can serve a foreign market. I observe the economic effects of environmental policy by expanding the model to include the enterprise costs of environmental protection. If pollution/environmental harm are by-products of production processes, environmental regulations would represent a variable 'cost' to production in those industries. As a result, enterprises in countries with high environmental standards would face higher variable production costs which would affect relative profitability. One would expect that these enterprises, all else equal, would act in arbitrage and locate production processes based on relative country levels of environmental regulations until rates of return are equalized.

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of measuring such a sweeping policy change, most studies in the PHH literature have sought to evaluate the flow of trade and FDI following alterations in levels of environmental regulations.

A second contribution of this paper is the explicit recognition that exports and FDI are determined jointly, and only a combination of both can provide an accurate view of enterprise location decisions. According to the theoretical model, heterogeneous enterprises select into exporting or FDI based on their respective levels of productivity and the costs associated with each option. Analyzing only one of these variables thus introduces omitted variable bias from ignoring the location decisions of enterprises that chose the other. The literature regarding the pollution haven hypothesis is divided into two camps based on the dependent variable of choice: FDI or trade. Most studies attempt to evaluate the flow of trade or FDI resulting from differences in the levels of environmental standards/regulation across countries and over time. Assessing trade flows would account for a change in the flow or composition of goods as a result of enterprise relocation[3], whereas an investigation regarding FDI would reveal movement of the enterprises themselves[4]. However, observing trade flows alone only provides an indirect assessment of the pollution haven hypothesis because this method does not measure the actual movement of enterprises – only possible consequences of the movement. Alterations in trade flows follow the movement of enterprises abroad, but only if it is assumed that these enterprises then continue sending their production to the home country. This assumption misses enterprise production relocation that does not result in trade back to the home country. Observing FDI flows alone also encounters problems related to those of only observing trade flows. Similar to the trade flow pollution haven literature, an examination of changes in the levels of FDI by itself could ignore the location decisions of those enterprises that did not relocate production processes. As a result, any analysis of the PHH with

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[3] Van Beers and Van den Bergh (1997) conclude the existence of a modest pollution haven effect and Levinson and Taylor (2008) determine a significant effect of pollution abatement costs on increasing imports, but the majority of the literature on trade flows fails to confirm the pollution haven hypothesis (See: Ederington, Levinson, and Minier (2004) or Harris, Konya, and Matyas (2002))

[4] Similar to the trade camp, analysis of the pollution haven hypothesis in terms of FDI flows has been equally inconclusive. Multiple studies have examined enterprise movements in and out of the United States (See: Keller and Levinson (2001), Xing and Kolstad (2000), Kellenberg (2008)), although two recent papers have used France and Germany as their points of reference (See: Kheder and Zugravu (2008), and Wagner and Timmins (2008) respectively). Much of the research involving economic flows from a single developed country have concluded modest to significant pollution haven effects, but the few studies that have observed FDI flows in and out of multiple countries have all failed to find any evidence in support of the pollution haven hypothesis (See: Letchumanan and Kodama (2000), Eskeland and Harrison (2003), Javorcik (2004)).

regard to enterprise production location is biased without the joint inclusion of trade and FDI, and an examination including both exports and FDI, as is completed in this paper, is needed.

Finally, a third contribution of this paper is a large improvement in the empirical data used to assess the PHH. This study's data not only provides greater breadth and accuracy in the results, but also produces the ability to observe differential effects across country development status as well as *de jure* and *de facto* environmental standards. I use bilateral data covering trade and investment from 30 OECD countries to 70 total countries (the 30 OECD countries plus 40 non-OECD countries) from around the world to provide my conclusions with widespread international coverage in contrast to the majority of existing studies. Although a few studies in the literature observe trade/FDI flows for multiple countries, each of these papers focuses on a select region or grouping of countries such as OECD[5], Eastern Europe[6], or a few developing states[7]. As a result, the empirical outcomes must be extrapolated widely in order to make any conclusions about the pollution haven hypothesis as a whole. Many studies also extrapolate their results from the behavior of enterprises from a single developed country like Germany[8], France[9], or the United States[10]. Therefore, this paper adds valuable insight to the pollution haven hypothesis debate by expanding the international coverage. I also measure environmental standards by using responses to survey questions regarding both regulatory stringency and regulatory enforcement taken from the Executive Opinion Survey administered each year by the World Economic Forum. This data avoids the bias of previous studies associated with measuring environmental regulations via pollution abatement costs[11], environmental performance[12], or proxy combinations of unlike variables[13], and the additional insight from the environmental enforcement variable enables this research specifically to assess

[5] See: Van Beers and Van den Bergh (1997), Harris et al (2002)
[6] See: Javorcik et al (2004)
[7] Eskeland and Harrison (2003)
[8] See: Wagner and Timmins (2008)
[9] See: Kheder and Zugravu (2008)
[10] See: Keller and Levinson (2001), Xing and Kolstad (2000), Kellenberg (2008)
[11] See: Eskeland and Harrison (2003), Keller and Levinson (2001), Levinson and Taylor (2008)
[12] See: Xing and Kolstad (2000)
[13] See: Javorcik et al (2004), Kheder and Zugravu (2008)

environmental laws and protections in both a *de jure* and *de facto* manner. The possible dichotomies between developed and developing countries and environmental regulations and their enforcement have never before been analyzed in this context.

The empirical results of this study suggest the plausible existence of a global pollution haven effect – enterprises choosing to locate production where environmental standards are lowest – for location decisions of OECD enterprises across developed and developing countries representing all regions of the world. Throughout all statistical estimations, greater discrepancies between higher levels of domestic (foreign) environmental regulation/enforcement and lax foreign (domestic) environmental regulation/enforcement correspond with lower (higher) ratios of exports to FDI from the domestic country to the foreign country. These results indicate that, all else equal, enterprises locate production where environmental standards are most lax, but the findings are not quite statistically significant at the .10 level for the total sample. However, the results change when the sample is split based on whether the 'foreign' or host country in each country pair is developed or developing. When only developed countries are included as potential hosts, no such pollution haven evidence is found. In contrast, when only developing countries are included as possible foreign enterprise destinations and environmental regulatory enforcement is used to reflect environmental standards, observed pollution haven effects are much more intense and statistically significant at approximately the .01 level. This finding further backs the pollution haven hypothesis, as the logic of the hypothesis indicates that developing countries would have more incentive to become 'pollution havens.'

The rest of the paper is structured as follows: the next section outlines the theoretical framework and the basis of the econometric estimation, section 3 summarizes the key data and explains its appropriateness, section 4 reports, describes, and analyzes the results, and section 5 concludes.

2. Methodology

The main theoretical contribution of this paper is to extend a production location decision model to assess the pollution haven hypothesis and the consequential alteration to the typically-used dependent variable. While all of the literature regarding the pollution haven hypothesis focuses on either trade or foreign direct investment, I follow the proximity-concentration tradeoff gravity model of enterprise location decision derived by Brainard (1993) and expanded by Helpman, Melitz, and Yeaple (2004) in order to more completely capture the location decisions of all enterprises.

This model explains enterprise choice to engage in exports or FDI as a trade-off motivated by the differences in costs and revenue potential associated with either option. As such, instead of observing a single variable such as net exports or total outward FDI as the dependent variable, I utilize a ratio of exports to foreign direct investment flows among country pairs as the dependent variable in the estimation equation. The advantage of this method is that it captures both ways in which an enterprise can serve a foreign market.

The location tradeoff in question is referred to by previous literature[14] as the proximity-concentration tradeoff[15], which states that enterprises will engage in FDI abroad when the relative gains from avoiding the costs associated with trade outweigh the costs of setting up production in more than one market. In the following model with heterogeneous enterprises, each enterprise determines for itself whether it will serve the foreign market in addition to the domestic market, and whether or not it will do so via exports or FDI. Although FDI contains lower variable costs relative to exporting due to avoiding trade costs, it involves higher fixed costs associated with doubling production facilities. The inclusion of

[14] See: Helpman et al 2004

[15] Two general theoretical explanations describe the enterprise production location choice trade-off: the proximity-concentration hypothesis and the factor proportions hypothesis. The former explains horizontal enterprise expansion, while the latter explains vertical expansion abroad. Although vertical expansion is an important aspect of enterprise location choice, due to the many industry-specific intricacies associated with separating production stages vertically, this model will focus on explaining horizontal expansion.

enterprise costs of environmental protection adds another variable cost differentiated across countries and provides a new wrinkle in the traditional tradeoff.

All previous studies regarding the pollution haven hypothesis have focused only on one of these two dependent variables and therefore contain omitted-variable bias resulting from ignoring some of the production location decisions made by enterprises in a particular country. I expand the respective literatures regarding both the pollution haven hypothesis and the enterprise location trade-off by including a policy variable representing environmental regulations as a variable cost to production specific to each country. As a result, this framework illustrates that enterprises producing in countries with higher environmental standards experience higher production costs. For a given market potential, enterprises would therefore desire to locate in countries with lower environmental standards. A relative increase in domestic country environmental regulation/enforcement would thus result in a larger incentive for enterprises to choose FDI in the location trade-off and would be reflected in a smaller ratio of exports to FDI among country pairs.

2.1 Production and Consumption

As in Helpman et al (2004), there are *N* countries in the world that use labor in order to produce varying amounts of a differentiated good *h*. Each enterprise in country *i* bears a fixed cost F_E in order to enter sector *h* and then draws a value of a productivity coefficient *a* from a distribution *G(a)* measured in labor-per-unit-output. After learning its level of productivity, the enterprise can then decide whether or not to produce output or exit; enterprises that stay in the market engage in monopolistic competition. If an enterprise chooses to produce, it will then bear additional fixed costs F_D. Conditional on staying in the industry, enterprises may choose to export to a foreign market *j*. If they do so, they will incur additional fixed costs F_X per foreign market. This cost variable can be thought of as the costs of creating a distributional network in country *j*. On the other hand, if an enterprise chooses to serve a foreign market through foreign direct investment instead of exports, it will incur fixed costs F_I per foreign market which include the distributional network costs of F_X as well as the costs associated with business start-up and forming a production facility that are included in F_D. As a result, the difference between F_I and F_X provides an index of the plant level returns to scale in sector *h*. All goods that are exported from country *i* to country *j* follow melting-iceberg transport costs $\tau^{ij} > 1$ – meaning that τ^{ij} units of the good must be transported from country *i* to country *j* in order for one unit of the good to arrive.

Consumer preferences for the differentiated variations of the good *h* are distributed with standard CES form and exhibit an elasticity of substitution $\varepsilon = \frac{1}{(1-\alpha)} > 1$. Consumers thus demonstrate a demand function $A^i p^{-\varepsilon}$ for every variety of product h in country *i* where *p* refers to the price of each variety and A^i is a level of demand that is exogenous in the eyes of each supplier. Due to the conditions of monopolistic competition, the price consumers face is a combination of an enterprise's variable cost of producing each unit of the good and any additional markups. In the model developed in Helpman et al (2004), the variable cost of producing each unit is the measure of labor-per-unit-output *a* multiplied by the wage rate w^i. However, this paper's addition to the model is a measure of environmental regulatory strictness φ^i which can be viewed as a kind of pollution tax – a variable production cost associated with the costs of the environmental consequences of an enterprise's production. It is enforced by each country's government. As a result, φ^i will vary among countries based on the differing levels of environmental standards/protection. Therefore, each variety is sold domestically at price $p = \frac{\varphi^i w^i a}{\alpha}$ where φ^i refers to the level of environmental regulations in country *i*, *a* refers to each enterprises' level of productivity, w^i refers to the wage rate in country *i*, and $\frac{1}{\alpha}$ refers to a markup factor.

An enterprise in country *i* will always serve the domestic market so long as it makes positive profits in sector *h*, and, if it stays in the industry, it can also choose to serve a foreign market *j*. If an enterprise chooses to export – if its drawn productivity level allows it to be profitable in exporting as explained in the next section – it will sell its variety of good h at price $p = \frac{\varphi^i \tau^{ij} w^i a}{\alpha}$ taking into account the additional variable costs τ^{ij} arising from shipping and transport. Similar to the domestic price, the price charged by an enterprise FDI subsidiary in a foreign market country *j* is described by $p = \frac{\varphi^j w^j a}{\alpha}$.

Assuming that $w^i = 1$ across all countries for mathematical simplicity, it follows that the demand function $A^i p^{-\varepsilon}$ implies an output of $A^i \left(\frac{\varphi^i a}{\alpha}\right)^{-\varepsilon}$ for the domestic market, $A^j \left(\frac{\varphi^i \tau^{ij} a}{\alpha}\right)^{-\varepsilon}$ for exports, and $A^j \left(\frac{\varphi^j a}{\alpha}\right)^{-\varepsilon}$ for foreign subsidiary sales. Total variable costs of production resulting from serving the domestic market therefore equal $\varphi^i a A^i \left(\frac{\varphi^i a}{\alpha}\right)^{-\varepsilon}$. The additional variable costs involved with exporting from country *i* to a foreign country *j* equal $\varphi^i \tau^{ij} a A^j \left(\frac{\varphi^i \tau^{ij} a}{\alpha}\right)^{-\varepsilon}$ whereas the additional variable costs involved with FDI production in country *j* equal $\varphi^j a A^j \left(\frac{\varphi^j a}{\alpha}\right)^{-\varepsilon}$. Combining the revenue and costs functions yields the following equations indicating the profits from serving the domestic market in country *i*, the additional profits from serving the foreign market country *j* via exports, and the additional profits from serving country *j* through FDI subsidiary sales respectively:

(1) $\pi_D^i = \left(\varphi^i a\right)^{1-\varepsilon} B^i - F_D$

(2) $\pi_X^{ij} = \left(\varphi^i \tau^{ij} a\right)^{1-\varepsilon} B^j - F_X$

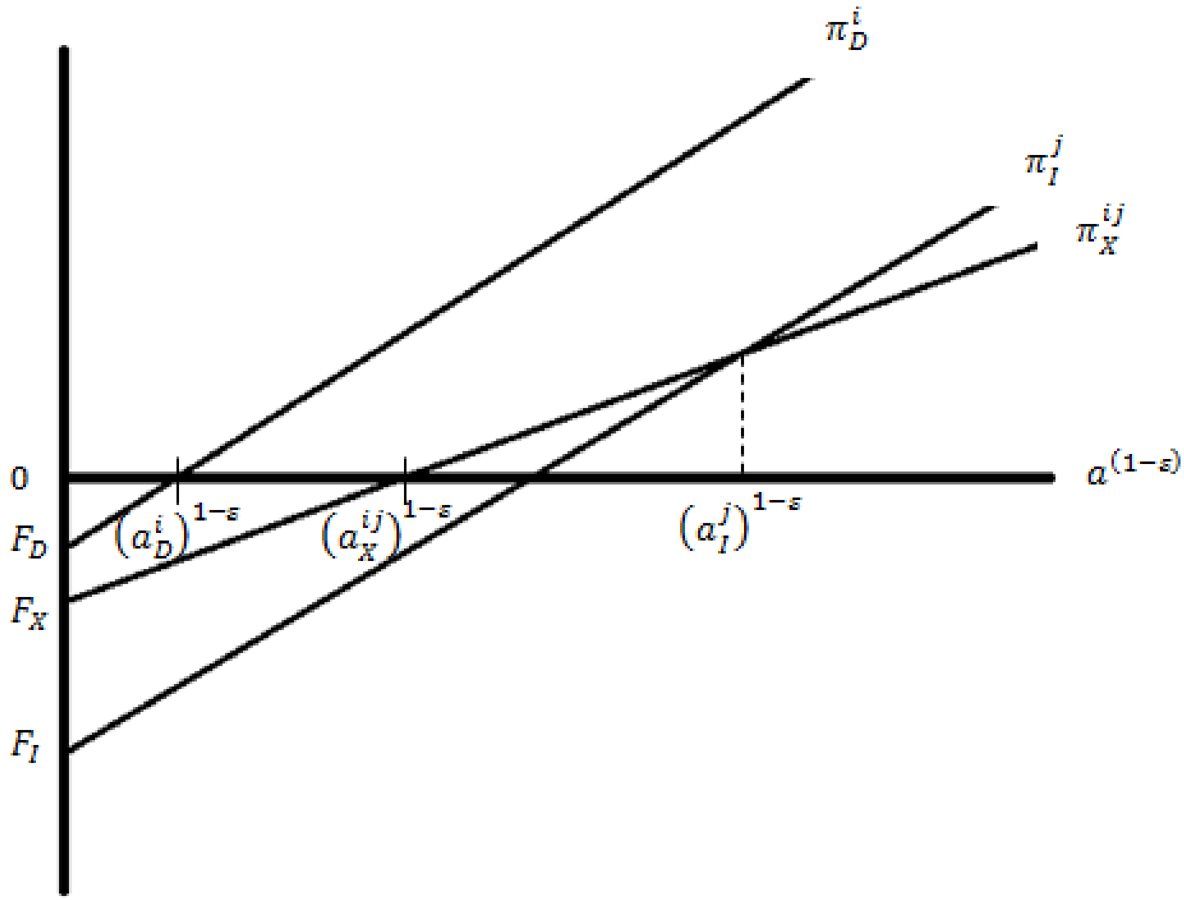
(3) $\pi_I^j = \left(\varphi^j a\right)^{1-\varepsilon} B^j - F_I$

where $B^i = \frac{(1-\alpha)A^i}{(\alpha)^{1-\varepsilon}}$ and $B^j = \frac{(1-\alpha)A^j}{(\alpha)^{1-\varepsilon}}$. The three profit functions produce the graph in Figure 1 where *D*, *X*, and *I* are the profit functions for domestic sales, export sales, and FDI subsidiary sales respectively.

Figure 1 represents the three profit functions if $B^i = B^j$ and $\varphi^i = \varphi^j$. In this specific case, the functions π_D^i and π_I^j are parallel, but the profits from FDI are lower because of the higher fixed costs F_I. In contrast, while the intercept of π_X^{ij} is more positive than π_I^j because $F_I > F_X$, the slope is flatter because of the trade costs τ^{ij}.

Figure 1

Graph indicating the profit functions of domestic, export, and FDI sales with respect to enterprise productivity and the productivity cutoffs that govern which enterprises choose to engage in which method of serving the market



2.2 Sorting

As illustrated, the heterogeneity of enterprise productivity in the coefficient *a* leads to three productivity cutoffs. Enterprises with levels of labor-per-unit-output productivity below the cutoff $\left(a_D^i\right)^{1-\varepsilon}$ will not be profitable even in only serving the domestic market in country *i* and will thus exit sector *h*. Enterprises with productivity levels falling between $\left(a_X^{ij}\right)^{1-\varepsilon}$ and $\left(a_D^i\right)^{1-\varepsilon}$ will serve the domestic market, but will not engage in serving the foreign market country *j* because, at these productivity levels, the additional costs of serving the foreign market cause these enterprises to be unprofitable. Productivity levels between $\left(a_I^j\right)^{1-\varepsilon}$ and $\left(a_X^{ij}\right)^{1-\varepsilon}$ will result in enterprises serving the foreign market via exports in addition to the domestic market, whereas productivity levels above $\left(a_I^j\right)^{1-\varepsilon}$ will result in enterprises serving the foreign market via FDI subsidiary production in addition to the domestic market. The productivity cutoffs in the model make it possible for all three types of enterprises to exist in the world economy: domestic serving only, exporting, and FDI. It is assumed that $\left(a_D^i\right)^{1-\varepsilon} < \left(a_X^{ij}\right)^{1-\varepsilon} < \left(a_I^j\right)^{1-\varepsilon}$. Solving for the values of these productivity cutoffs thus produces the following constraint for the value of the fixed costs associated with each type of production.

(4) $$\frac{F_D}{B^i\left(\varphi^i\right)^{1-\varepsilon}} < \frac{F_X}{B^j\left(\varphi^i\tau^{ij}\right)^{1-\varepsilon}} < \frac{F_I - F_X}{B^j\left[\left(\varphi^j\right)^{1-\varepsilon} - \left(\varphi^i\tau^{ij}\right)^{1-\varepsilon}\right]}$$

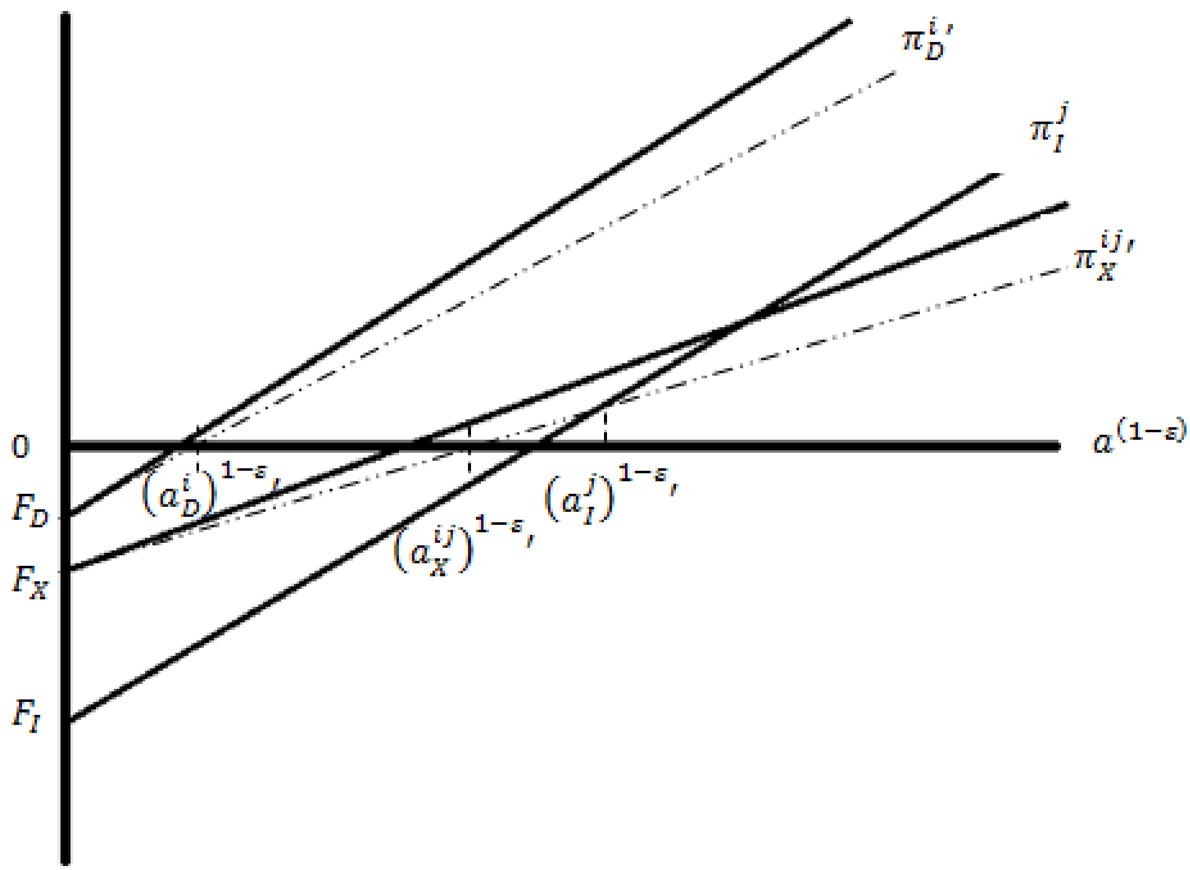
Because the productivity cutoff determines whether or not enterprises engage in FDI or exports, $\left(a_I^j\right)^{1-\varepsilon}$ can be viewed as an index for the ratio of the share of exports to the share of FDI from country *i* to country *j* given a productivity distribution *G(a)*. If this cutoff increases as a result of some change in the other variables, fewer enterprises will find it profitable to engage in FDI. The ratio of exports to FDI will thus increase from country *i* to country *j*. Therefore, the effect of differences in relative country environmental regulations on the enterprise production location decision to engage in FDI or exports can be observed by the effect of the environmental policy variables φ^i and φ^j on the level of $\left(a_I^j\right)^{1-\varepsilon}$ – the cutoff at which FDI becomes more profitable than exports.

Within a particular productivity distribution *G(a)*, higher values of $\left(a_I^j\right)^{1-\varepsilon}$ correspond with greater shares of exports relative to FDI for country pairs *ij* because relatively fewer enterprises would find FDI subsidiary production to be more profitable than exports, and vice versa. As shown in Figure 2, FDI is more profitable than exports for a relatively larger amount of enterprises as the productivity level at which $\pi_I^j > \pi_X^{ij}$ decreases. Reiterating what is predicted by Helpman et al (2004), higher trade costs τ^{ij} lower the value of $\left(a_I^j\right)^{1-\varepsilon}$ and thus correspond with smaller relative shares of exports as FDI becomes more profitable for a greater number of enterprises. Similarly, $\left(a_I^j\right)^{1-\varepsilon}$ is increasing in the difference between the fixed costs of FDI and export meaning that the ratio of exports to FDI is larger when the fixed costs of investment are significantly higher than the fixed costs of export. The productivity cutoff is also decreasing in the measure of foreign market demand B^j. This result makes sense because larger market demands would spread the higher fixed costs of FDI F_I over a greater level of output.

Finally, $\left(a_I^j\right)^{1-\varepsilon}$ is decreasing in stricter relative levels of domestic environmental regulation φ^i compared to foreign environmental regulation φ^j. In contrast, if the level of foreign environmental regulation is relatively more strict and the associated enterprise cost φ^j is greater than the domestic cost φ^i, the productivity cutoff $\left(a_I^j\right)^{1-\varepsilon}$ will be greater; a country pair *ij* will experience a larger ratio of exports to FDI from *i* to *j* as producing in the home country and exporting to the foreign country becomes relatively more profitable than FDI for a larger number of enterprises. These results reflect the outcome predicted by the pollution haven hypothesis. In any respective country pair, enterprises will have a greater incentive to locate the production of their variety of good *h* in the country with the relatively less strict environmental standards in order to avoid some of the costs associated with the environmental

Figure 2

Graph illustrating the changes to the productivity cutoffs in Figure 1 after an increase in home country environmental standards resulting in greater variable costs for domestic production. Given a distribution of enterprise productivity, the gap between the productivity cutoffs for exports and FDI decreases, relative productivity changes, and therefore relatively fewer enterprises choose to export and relatively more enterprises choose to engage in FDI.



consequences of their production. The larger is the difference in environmental standards between countries, the greater the impact will be on the ratio of exports to FDI. Figure 2 above illustrates the comparative statics of an increase in domestic environmental regulation all else equal.

2.3 Ratio of Trade to FDI

The ratio of the shares of revenue between exports and FDI for each country *ij* pair is a representation of the share of enterprises engaging in exports to the share of enterprises engaging in FDI and provides the same intuition as is detailed above. Integrating the revenue functions for both export and FDI production individually with respect to the *G(a)* productivity distribution yields the total industry *h* export and FDI revenues from country *i* to country *j*. Obtaining the ratio of the revenues therefore results in the identity below where S_X^{ij} is the share of revenue from exports and S_I^{ij} is the share of revenue from FDI.

$$\textbf{(5)}\ \frac{S_X^{ij}}{S_I^{ij}} = \left(\frac{\varphi^i}{\varphi^j}\right)^{1-\varepsilon} \left(\tau^{ij}\right)^{1-\varepsilon} \left[\frac{\int_{a_X^{ij}}^{a_I^j} (a)^{1-\varepsilon} dG(a)}{\int_{a_I^j}^{\infty} (a)^{1-\varepsilon} dG(a)}\right]$$

Since the elasticity of substitution ε is greater than one, the equation for the ratio of revenue share of exports to FDI is decreasing in the ratio of domestic environmental regulatory stringency to foreign environmental regulatory stringency $\frac{\varphi^i}{\varphi^j}$, decreasing in the trade costs τ^{ij} from country *i* to country *j*, increasing in the total number of enterprises with productivity levels that make exports profitable, and decreasing in the total number of enterprises with productivity levels that make FDI profitable. Although the variablesφ^i, φ^j, and τ^{ij} each exhibit direct effects on the ratio of exports to FDI, they also provide indirect effects because, as discussed above, they also alter the productivity cutoffs that are used in the integrals of equation (5). These comparative statics reflect the expected effects on the dependent variable $\frac{S_X^{ij}}{S_I^{ij}}$. For example, an increase in the discrepancy between a strict level of domestic environmental regulations and lax foreign environmental regulations decreases the share of enterprises that locate production domestically and serve the foreign market through exporting relative to the share of enterprises that locate production abroad and serve the foreign market via FDI.

However, equation (5) can be decomposed further if the shape of the dispersion of enterprise productivity is assumed to follow a Pareto distribution. Using the Pareto distribution as the benchmark in parametrizing *G(a)*, it follows that $\left[\frac{\int_{a_X^{ij}}^{a_I^j}(a)^{1-\varepsilon}dG(a)}{\int_{a_I^j}^{\infty}(a)^{1-\varepsilon}dG(a)}\right]$ is equal to $\left(\frac{a_X}{a_I}\right)^{k-(\varepsilon-1)}$ for every a_X and a_I where $k-(\varepsilon-1)$ represents the shape parameter of the distribution. Combined with the identities of the productivity cutoffs in equation (4), equation (5) can thus be rewritten as:

(6) $$\frac{S_X^{ij}}{S_I^{ij}} = \left(\frac{\varphi^i}{\varphi^j}\right)^{1-\varepsilon}\left(\tau^{ij}\right)^{1-\varepsilon}\left[\left(\frac{F_I-F_X}{F_X}\right)\left(\frac{\left(\varphi^i\right)^{1-\varepsilon}\left(\tau^{ij}\right)^{1-\varepsilon}}{\left(\varphi^j\right)^{1-\varepsilon}-\left(\varphi^i\right)^{1-\varepsilon}\left(\tau^{ij}\right)^{1-\varepsilon}}\right)\right]^{\frac{k-(\varepsilon-1)}{\varepsilon-1}}$$

Equation (6) is the key result of this paper. This final equation clearly exhibits the direct effects of the cost variables on the intensive margins or volumes of both trade and foreign direct investment as well as the indirect effects of the cost variables on the extensive margins or number of enterprises which elect to engage in either option. Both fixed and variable costs are present in the calculation of the extensive margin, as both affect the selection tradeoff. Equation (6) also shows that the relative level of exports is increasing in the Pareto shape parameter *k* which reflects the findings of Helpman et al (2004) who demonstrate that sectors with higher levels of dispersion in the distribution of enterprise productivity have lower levels of relative export sales.

The derived gravity model of enterprise location details a situation in which enterprises desiring to serve a foreign market can do so in two ways: through home production and exports or foreign direct investment. Both of these options face associated costs, and enterprises respond by locating production domestically or abroad via FDI according to which will be more profitable. Exporting has lower fixed costs but higher per-unit variable production costs compared to FDI. When environmental regulation is added into the model as an additional variable cost resulting from consequences of pollution, environmental destruction related to production, etc., changes in the cost structures impact the trade-off between FDI and exports. For each country *ij* pair, the model makes predictions in line with the pollution haven hypothesis. Higher relative levels of environmental regulation in the home country (represented by higher φ^i) will correspond with lower values for the ratio of exports to FDI from *i* to *j* and higher relative levels of environmental regulation in the foreign country (represented by higher φ^j) will correspond with higher values for the ratio of exports to FDI for each country pair. Thus, the model exhibits that enterprises respond to environmental protections by locating their production processes where environmental standards are relatively less strict.

2.4 Estimation Equation

The ratio of enterprise exports to foreign direct investment not only captures a more complete assessment of enterprise location decisions as opposed to observing only one of the two, but it also provides a useful function in the empirical estimation. The act of taking the ratio effectively divides out and eliminates all bilateral variables that impact both exports and foreign direct investment evenly within a given country pair.

In order to account for the country-specific variables such as wages (that were previously assumed in the theory as equal to one for mathematical simplicity) and the country-level fixed costs present in equation (6), it is necessary to also include country fixed effects in the estimation. What will remain empirically therefore are the variables present in the final equation of the theoretical model: bilateral variables within country pairs that have differing effects on the composition of flows of exports and FDI. Although data restrictions associated with combining trade, FDI, and environmental data prevent the construction of a direct control for enterprise heterogeneity and the extensive margin of trade and FDI within country pairs as presented in the integrals of the model[16], the fixed effects should still provide a partial, indirect estimate of the extensive margin via the country-specific enterprise productivity Pareto distribution shape parameters k_i.

In order to empirically evaluate equation (6), I thus estimate the following regression using ordinary least squares:

$$\textbf{(7)}\ \ ln\frac{Exports}{FDI}ij = \beta_i x'_{ij} + \theta_i z'_{ij} + \omega_i y'_{ij} + \rho_i E'_i + \delta_i I'_j + \epsilon_{ij}$$

where: x'_{ij} is a vector of trade costs, z'_{ij} is a vector of the ratio of environmental standards between country pairs, y'_{ij} is a vector of additional, fixed cost-influential bilateral characteristics among country pairs, E'_i is a vector of exporter country fixed effects, I'_j is a vector of importer country fixed effects, and ϵ_{ij} is the error term.

3. Measurement and Data

Based on the theory, in order to estimate the impact of country environmental standards on the enterprise location decision between exports and FDI, I require data that measures bilateral trade costs, relative environmental standards, and other bilateral variables that impact fixed costs. Specifically, the results to follow estimate the equation below:

$$\textbf{(8)}\ \ ln\frac{Exports}{FDI}ij = \beta_0 + \beta_1 EnvironRatio_{ij} + \beta_2 Distance_{ij} + \beta_3 Tariff_{ij} + \beta_4 Border_{ij} + \beta_5 Colony_{ij} + \beta_6 IMR + \epsilon_{ij}$$

where: *EnvironRatio* is the ratio between country *i'*s and country *j'*s score averages from the responses to the World Economic Forum Executive Opinion Survey regarding the either the level of environmental

[16] See: Helpman et al (2008) for details regarding the enterprise heterogeneity control variable

regulation or the level of environmental enforcement for the year 2011, *Distance* is the geographic distance between the most populous cities in each country pair and utilized as a proxy for shipping costs, *Tariff* is an ad valorem average measure of trade taxes across industries for each bilateral country pair in the year 2011, *Border* is a binary variable equal to 1 if the country pair shares a common border, *Colony* is a binary variable equal to 1 if a country pair has ever had a colonial relationship, and *IMR* is the Inverse Mills Ratio used as the classic Heckman control for sample selection bias.[17]

To control for sample selection, it is necessary to include the Heckman control variable known as the Inverse Mills Ratio because any observations with zero FDI will be dropped when the ratio is taken, and any observations with zero trade will be dropped when taking the natural log. This process creates sample selection bias in the statistical estimation. The Inverse Mills Ratio is calculated from first generating a binary variable R_{ij} equal to one if an observation is included in the estimation sample and zero if it is not, running a Probit regression of the generated binary variable with the independent variables in addition to an exclusionary restriction variable[18], and then taking the ratio of the probability density function to the cumulative distribution function for the predicted values of the Probit.[19] The functional form of the Probit is as follows:

(9) $$p_{ij} = \Pr(R_{ij} = 1 | observed\ variables)$$
$$= \Phi(\beta_i x'_{ij} + \theta_i z'_{ij} + \omega_i y'_{ij} + \rho_i E'_i + \delta_i I'_j + \gamma_i \xi'_{ij})$$

where Φ(-) is the cumulative distribution function of the unit-normal distribution, and ξ'_{ij} is a vector of the exclusionary restriction variable – in this case, a binary variable equal to one if the given country pair shares a common language and zero if it does not.

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[17] Before running the tests, I take the natural log of the dependent variable Exports/FDI in order to correct for heteroscedasticity. Without doing so, both the Breusch-Pagan and White tests for heteroscedasticity show that the error term is not distributed evenly across the range of the data thus invalidating OLS estimation. Taking the natural log of the dependent variable produces homoscedasticity and allows for the use of OLS.

[18] I follow Helpman et al (2008) and use the binary variable *Common Language* as the exclusionary restriction variable

[19] For additional information regarding the econometric foundations of the sample selection bias correction technique using the Inverse Mills Ratio, see: Heckman (1979)

3.1 Data Description

This study includes widespread bilateral trade/investment data, in contrast to previous research, lending this paper greater accuracy in commenting on the existence of pollution haven effects across the world. Although the availability of bilateral FDI data still constrains the dataset to focus on only the decisions of OECD enterprises, the data includes bilateral trade/investment flows for the year 2012 from 30 OECD countries to 70 countries (30 OECD and 40 non-OECD) representing all major regions of the world and approximately evenly split in terms of development status. The foreign direct investment data is taken from OECDStat and the export data is taken from the UN Comtrade database. For the sake of the estimation, any negative FDI values are coded as zeros, and all confidential values are excluded.

Because the environmental policy variable is not strictly defined by an observable numerical value, and even the existence of ordinal ranking environmental policy variables is lacking, most previous research has sought to proxy this variable through either a measure of environmental performance[20], total pollution abatement expenditures[21], or a combination of multiple characteristics assumed to relate to the level of regulation[22]. As noted in Levinson and Taylor (2008), using abatement costs introduces bias away from a pollution haven effect because, if enterprises have already relocated at the time abatement data is collected, the remaining enterprises would likely have below-average abatement costs. Measures of environmental performance, such as sulfur dioxide levels in Xing and Kolstad (2002), are also dubious as proxies for environmental regulation because they require the assumption that the relationship between the amounts of the pollutant emitted and the laxity of environmental regulations be strictly increasing. Lastly, the combinations of various characteristics like ‘number of NGOs’ or ‘international environmental treaties ratified’ cannot be viewed as an accurate assessment of country regulatory stringency and enforcement because of how loosely these variables are tied to the variable for which they are a proxy.

[20] See: Xing and Kolstad (2000)
[21] See: Eskeland and Harrison (2003), Keller and Levinson (2001), Levinson and Taylor (2008)
[22] See: Javorcik et al (2004), Kheder and Zugravu (2008)

Instead, I follow Kellenberg (2008) and Wagner and Timmins (2008) by using a recent dataset that provides multiple benefits to pollution haven research. In order to avoid the bias introduced by various proxies of environmental regulation, I use survey data compiled in the yearly Executive Opinion Survey for the Global Competitiveness Report administered by the World Economic Forum. The EOS surveys business leaders around the world on many topics including environmental regulatory framework and environmental enforcement with a yearly average of around eighty to ninety respondents within each of the approximate 140 represented economies. This data presents advantages in that it has broad international coverage[23] and reflects the opinions of the business community which is the relevant population in analyzing enterprise location decisions. An additional interesting advantage of this environmental data is the fact that the questions regarding the stringency of environmental regulations and the strength of environmental regulatory enforcement provide the ability to assess both the environmental letter of the law as well as whether or not the law is actually applied and enforced in reality. While these two measures are correlated, they still differ and contribute different information to the question raised by the pollution haven hypothesis: if responsive to country environmental standards at all, are enterprises responsive to the existence of the law itself or whether or not the law is strictly enforced?

Table 1 here

The results of this paper use the Executive Opinion Survey environmental data from the year 2011. Seventy of the surveyed economies are included in the empirical assessment. Both of the survey questions ask respondents to assign an ordinal ranking from one to seven where one is lax regulations or lenient levels of enforcement and seven is stringent regulations or strict enforcement. The responses are then averaged within each country for every year. Out of the sample of seventy economies from the year 2011, both variables have means of around four and standard deviations of approximately one. The standard deviations illustrate that there is a fair amount of country variation. The measures also appear to follow relatively normal but skewed right distributions.

[23] See Appendix for the wording of the questions

Figures 3 and 4 here

Although I am using trade and investment data for the year 2012, I have decided to include the environmental data for the year 2011 in order to account for the lag in business perceptions. It would not make sense to use environmental regulatory data for the same year as the trade and FDI data because enterprises would not have had the chance to ‘view’ the country environmental standards before making their production decisions. It could, in fact, be argued that even earlier environmental data would be appropriate given that enterprise production decisions are likely planned long in advance.

Other common gravity model variables representing distance, border contiguity, and colonial history are taken from the CEPII database GeoDist, and tariff data for the year 2011 is taken from Fenestra and Romalis (2014). I use distance as a proxy variable for transport costs and an average measure of ad valorem trade taxes across industries as a measure of tariff-based trade costs, both of which are used to estimate the τ^{ij} term in the theory. I include the binary measures of border contiguity and colonial history to account for additional country pair characteristics that may affect trade or FDI either through trade costs τ^{ij} or the fixed cost terms F_I or F_X.

4. Results

The results to follow first apply equation (8) to estimate (6) for the full sample with environmental standards measured by both the environmental regulatory stringency and environmental regulatory enforcement variables, then split the sample in half based on whether or not the host country in each country pair is developed or developing, and conclude by estimating (6) for specific pollution-intensive industries with the addition of enterprise heterogeneity controls.

The empirical estimations presented in Table 2 follow the regression in equation (8) and reflect the predictions of the model and the pollution haven hypothesis. The effects of the explanatory variables in the two models with fixed effects and robust standard errors are somewhat statistically significant with R-squared values of approximately .5. I find that the respective country *ij* ratios of both environmental regulation and environmental enforcement decrease the ratio of exports to foreign direct investment observed for each country ij pair. Due to the negative signs of the coefficients on the environmental standards variables, a higher relative level of domestic environmental regulatory stringency or environmental enforcement corresponds with a lower relative share of exports to FDI as enterprises have greater incentive to move production abroad and engage in FDI in order to avoid environment-related costs. This finding represents the core prediction of the pollution haven hypothesis. Although the effect of environmental regulation is not fully statistically significant in the full estimation with fixed effects, it's p-value is still low enough at .18 to warrant further inspection, and the fact that all regressions yield the same coefficient signs provide additional evidence for the robustness of the direction of the environmental variable's effect. Similarly, the coefficient on the ratio of environmental enforcement is negative across all estimations, and, although it is again not quite statistically significant in the full model estimation, its p-value of approximately .2 is small enough to point toward a possible systematic pollution haven effect with regard to environmental enforcement as well.

Therefore, it appears that relative differences in the levels of environmental regulatory stringency across countries have some effect on the enterprise location decision to either produce domestically and export or to produce abroad through FDI subsidiaries. As would be anticipated from the pollution haven hypothesis, enterprises are relatively more likely to produce in the country with lower environmental standards when seeking to serve a foreign market. This effect is observed to be stronger the greater the differential of environmental standards within a country pair.

The other gravity variables in the regressions also exhibit expected effects on the dependent variable. In the complete models for both measures of environmental standards with robust standard errors, the ratio of exports to FDI is decreasing in *Tariff* and *Colony.* Higher tariffs increase the variable costs of exporting, and, while prior or current colonial relationships may not provide a direct intuition for

Table 2

OLS regressions with sample selection controls measuring the effects of both environmental regulatory stringency and the strength of environmental enforcement on the dependent variable: the ratio of Exports over FDI (n = 949)

	Environmental Regulation			Environmental Enforcement		
Variable						
Regulation	-.7596***	-.8711***	-1.956	-	-	-
	(.2123)	(.0464)	(1.488)	-	-	-
Enforcement	-	-	-	-.7048***	-.7285***	-1.146
	-	-	-	(.1693)	(.1767)	(.9135)
Tariff	-	.0464***	-.0866	-	.0453***	-.0871
	-	(.0176)	(.0491)	-	(.0174)	(.0564)
Distance	-	-.00003*	.00012***	-	-.00003	.00012***
	-	(.00002)	(.00005)	-	(.00002)	(.00005)
Border	-	.6202**	.1091	-	.6302**	.1185
	-	(.3148)	(.2570)	-	(.3143)	(.2584)
Colony	-	-.9256***	-1.183***	-	-.9178***	-1.174***
	-	(.3294)	(.3078)	-	(.3290)	(.3072)
R^2			.4808			.4807
Fixed Effects	No	No	Yes	No	No	Yes
Robust SE	No	No	Yes	No	No	Yes

Standard errors in parentheses: $^*p < .10$, $^{**}p < .05$, $^{***}p < .01$

decreasing the share of exports relative to FDI, this observed effect seems logical as colonial ties between countries likely induce lower fixed costs stemming from similar language use, pre-existing economic relationships, etc. Since FDI incurs much higher fixed costs, it could stand to benefit more from colonial relationships. Sharing a border has a positive effect on the exports to FDI ratio as would be anticipated by the decrease in variable costs associated with immediate proximity. The one strange outcome of the estimation is the positive sign on the *Distance* coefficient. One would predict that *Distance* would have a negative effect on the ratio of exports to FDI because greater distances would increase variable transport costs and lower export profitability. It may be the case, however, that greater distances would cripple FDI to an even larger extent through increased costs of maintaining capacity. Although *Distance* and *Colony* are the only two out of the four gravity variables statistically significant at the .01 level, *Tariff* has a low p-value at .12.

4.1 Developmental Variation

The above estimations take an aggregated look at the model of enterprise location decision and the existence of pollution havens. However, it may be possible that pollution haven effects apply differently across differing groups of countries. If true, aggregating the group effects in the full sample could confound the estimated impacts of environmental standards on the ratio of exports to FDI and thus enterprise production location decisions. For example, does the observed impact of country environmental standards on enterprise location decisions change based on the developmental statuses of the two countries in each country pair? The conventional logic behind the assumptions of the pollution haven hypothesis would suggest that the environmental variables' effects on enterprise location might be greater when a developed country is the 'home' and a developing country is the 'host'; enterprises in higher income countries may be more able to 'shop around' for the cheapest production sites, while developing and lower income countries may be more desperate to concede to the desires of international business in pursuit of advancement in industrialization. I therefore create a development indicator variable that represents whether the host country is developed or developing and run the same regressions as before to check for any differential effects across groups.[24]

The results in Table 3 display an interesting dichotomy between both developed and developing countries as well as between the two measures of environmental standards: environmental regulatory stringency and environmental regulatory enforcement. It is clear that pollution haven effects are essentially non-existent when only developed countries are potential host countries. Neither of the coefficients on the environmental variables is anywhere close to being statistically significant, and the sign of the coefficient on environmental enforcement is even positive. In contrast, the effect of relative environmental regulations with developing country potential hosts is negative, much larger than before in absolute value, and has a p-value of approximately .13.

Most notable, however, is the observed effect of differing levels of enforcement of environmental standards on the ratio of exports to FDI when only developing countries are considered as host countries. Not only is the coefficient negative and larger than in previous regressions in absolute value, but the effect is also statistically significant at the .05 level and almost at the .01 level (p-value = .017). This result indicates that differences in country environmental standards have the greatest effect on enterprise location decisions (resulting in enterprises tending to locate where standards are lowest) when the potential host countries in question are developing states, and that the strongest pollution haven effects for developing countries arise when the measure of country environmental standards is how well environmental regulations are actually enforced – rather than simply how strict enacted regulations are on paper.

As the only study to date to examine the pollution haven hypothesis segmented by development group and by both letter of the law regulations and actual enforcement of environmental standards, this outcome is very insightful. Clearly, while this study does present some indication of the existence of global, systematic pollution haven effects on enterprise production location, these effects are not balanced

[24] I use the current United Nations' determination of which countries are 'developed' or 'developing'

Table 3

OLS regressions with sample selection controls measuring the effects of both environmental regulatory stringency and the strength of environmental enforcement on the dependent variable the ratio of Exports over FDI differentiated by host country development status

	Environmental Regulation		Environmental Enforcement	
Variable	*Developed*	*Developing*	*Developed*	*Developing*
Regulation	-1.3428	-4.2883	-	-
	(1.9830)	(2.8348)	-	-
Enforcement	-	-	.1373	-4.7227**
	-	-	(1.776)	(1.9646)
Tariff	.0166	-.0863	.0137	-.0854
	(.0685)	(.0630)	(.0687)	(.0622)
Distance	.00002	.00017***	.00002	.00016***
	(.00008)	(.00006)	(.00008)	(.00006)
Border	.1001	-1.5794**	.1361	-1.5505**
	(.2716)	(.7753)	(.2742)	(.7579)
Colony	-.9853**	-1.2315***	-1.0052**	-1.2110***
	(.4794)	(.4585)	(.4793)	(.4594)
R^2	.5031	.5632	.5034	.5682
n	530	419	530	419
Fixed Effects	Yes	Yes	Yes	Yes
Robust SE	Yes	Yes	Yes	Yes

Standard errors in parentheses: $*p < .10$, $**p < .05$, $***p < .01$

across developed and developing countries – a finding that could help explain the variability of previous research conclusions that do not segment the data by groups. When determining production location, this study finds that enterprises tend to locate production processes where environmental standards are relatively less strict, but that enterprises weigh relative differences in environmental standards in developing countries much more heavily. The largest influence of relative country environmental standards on enterprise production location also appears to come from – not regulatory promises – but rather the actual action of enforcing environmental protection.

4.2 Enterprise Heterogeneity

Of course, the above analysis suffers from a crucial caveat: the lack of a direct control for enterprise heterogeneity which underpins the selection process of enterprises into domestic production, exporting, or foreign direct investment. The previous estimations contain country fixed effects which should account for the country-specific distributions of enterprise heterogeneity, but fixed effects are only indirect controls for the effects of heterogeneity within country pair relationships. What is missing is thus a direct variable control for enterprise heterogeneity that directly accounts for the extensive margin of enterprises engaging in exports and FDI for each country pair. As briefly noted earlier in this paper, enterprise heterogeneity controls can be constructed via a process described by Helpman et al (2008) that utilizes the predicted values of export and FDI Probit regressions.

The first stage of the two stage estimation involves the same form of the Probit regression in equation (9) used to construct the sample selection bias for the previous results in this paper. For these results, however, two Probits are estimated replacing the indicator binary variable R_{ij} with new binary variables X_{ij} equal to one when country *i* exports to country *j* and zero if it does not, and I_{ij} equal to one when country *i* engages in FDI to country *j* and zero if it does not.

(10) $$p_{ij}^{X} = \Pr(X_{ij} = 1 | observed\ variables)$$

(11) $$p_{ij}^{I} = \Pr(I_{ij} = 1 | observed\ variables)$$

Let p_{ij}^{X} and p_{ij}^{I} be the predicted probabilities of exports and FDI from *i* to *j* respectfully, and let $z_{ijX}^{*} = \Phi^{-1}(p_{ij}^{X})$ and $z_{ijI}^{*} = \Phi^{-1}(p_{ij}^{I})$. Helpman et al (2008) show that consistent estimates for the selection of enterprises into export markets, defined by the authors as variable W_{ij} and present in this paper's model as the integral $\int_{a_X}^{a_{I_{ij}}^{j}}(a)^{1-\varepsilon}dG(a)$ in equation (5), can be obtained by $W_{ij} = \max[(z_{ijX}^{*})^{\delta} - 1, 0]$[25]. However, since this paper's model works with the ratio of the share of exports to the share of FDI, my estimate of $\left[\frac{\int_{a_X}^{a_{I_{ij}}^{j}}(a)^{1-\varepsilon}dG(a)}{\int_{a_I^{j}}^{\infty}(a)^{1-\varepsilon}dG(a)}\right]$ in equation (5) is obtained from the ratio $\max\left[\left(\frac{z_{ijX}^{*}}{Z_{ijI}^{*}}\right)^{\delta} - 1, 0\right]$. As a result, I include this control for enterprise heterogeneity and the selection of enterprises into export and FDI markets as a polynomial expression with terms z_{ijX}^{*}/z_{ijI}^{*}, $(z_{ijX}^{*}/z_{ijI}^{*})^{2}$, and $(z_{ijX}^{*}/z_{ijI}^{*})^{3}$[26]. The following regression equation also includes the Inverse Mills Ratio as the standard Heckman correction for sample selection bias into both the export $\eta_{ijX}^{*} = \phi(z_{ijX}^{*})/\Phi(z_{ijX}^{*})$ and FDI $\eta_{ijI}^{*} = \phi(z_{ijI}^{*})/\Phi(z_{ijI}^{*})$ markets. The sample selection bias controls address unobserved country-pair level shocks affecting selection into export and FDI relationships, and the enterprise heterogeneity controls address bias resulting from the selection of enterprises into exporting or FDI resulting from underlying, unobserved distributions of enterprise-level heterogeneity. The complete model can thus be estimated by:

(12) $$ln\frac{Exports}{FDI}ij = \beta_i x_{ij}' + \theta_i z_{ij}' + \omega_i y_{ij}' + \rho_i E_i' + \delta_i I_j' + \gamma_i \eta_{ijX}^{*} + \vartheta_i \eta_{ijI}^{*} + \lambda_i \frac{z_{ijX}^{*}}{z_{ijI}^{*}} + \kappa_i (z_{ijX}^{*}/z_{ijI}^{*})^{2} + \psi_i (z_{ijX}^{*}/z_{ijI}^{*})^{3} + \epsilon_{ij}$$

The ability to construct the heterogeneity control term requires zero values for both trade and FDI flows in order to successfully estimate the Probit regressions. When all commodities are included as exports, due to the data constraints that restrict the origin countries to only those in the OECD, there are

[25] In this equation, Helpman et al (2008) define $\delta = \sigma_{\eta}(k - \varepsilon + 1)/(\varepsilon - 1)$ where σ_{η} is the standard deviation of the error term for the estimation of the latent variable Z_{ij}, which is the same estimation equation used as the right-hand side of the Probit regressions

[26] Helpman et al (2008) also estimate the control using a polynomial expression

essentially no zero trade flow values for any country pairs in the dataset, effectively negating the possibility of running a Probit regression. However, focusing only on separate industries as possible exports allows for enough observed zero values to construct the heterogeneity control variables. Table 4 presents regressions assessing the effects of the environmental regulatory variable on the ratio of exports to FDI with exports split by three global industries based on SITC classifications. The industries were chosen with regard to their statuses as three of the most pollution-intensive global industries according to levels of pollution abatement costs in the U.S. and other OECD countries as well as emissions intensity computed by the World Bank in collaboration with the U.S. EPA[27]; these industries are *Chemical Materials and Products*, *Iron and Steel,* and *Non-Ferrous Metals.*

The results in Table 4 uses export data for the three pollution-intensive industries and enterprise heterogeneity controls and illustrates similar findings to the previous estimations. First and foremost, across all industries and specifications, higher relative levels of environmental regulation in the home (host) country for a given country pair result in a smaller (larger) share of exports relative to FDI – meaning that more enterprises choose to locate production where environmental regulations are least strict. While this effect is not quite statistically significant for industry *Iron and Steel* (p-value = .23), it is statistically significant for industries *Chemical Materials and Products* and *Non-Ferrous Metals.* With regard to the other explanatory variables, the effects of tariffs are generally negative on the ratio of exports to FDI, and the effects of common borders are generally positive on the dependent variable, meaning that tariffs increase incentives for FDI and contiguity increases the incentives for trade. The differences between the regressions with enterprise heterogeneity controls and the previous regressions are that: the effect of a prior colonial relationship loses its former negatively-significant effect on the ratio of exports to FDI, and the effect of distance is now negative and highly significant as would be predicted by common gravity models.

Still, the regressions with enterprise heterogeneity control variables also come with a crucial caveat because no international, bilateral foreign direct investment data broken down by industry

[27] For further information about industry classification, see: Mani and Wheeler (1999)

Table 4

OLS regressions with fixed effects and enterprise heterogeneity controls measuring the effects of environmental regulations on the ratio of Exports to FDI

	Chemical Products		Iron/Steel		Non-Ferrous Metals	
Variable	*n = 939*		*n = 909*			*n = 908*
Regulation	-3.5754**	-3.6046**	-1.3530	-2.0745	-2.9324	-3.5724*
	(1.6020)	(1.6030)	(1.7342)	(1.7420)	(1.8965)	(1.9442)
Tariff	-.0057	.0202	-.0666	-.0757	-.0142	-.00924
	.0541	(.0565)	(.0584)	(.0607)	(.0655)	(.0686)
Distance	-.00006**	-.00042***	-.00012***	-.00045***	-.00014***	-.00037**
	(.000028)	(.00015)	(.000029)	(.00016)	(.000034)	(.00018)
Border	-.0042	1.7974	.6477**	2.3738	.1157	1.4856
	(.3047)	(1.2680)	(.3256)	(1.3821)	(.3642)	(1.5196)
Colony	-.7517**	4.1794	-.4265	4.2348	-.4704	3.1664
	(.3218)	(2.7874)	(.3435)	(3.0419)	(.3840)	(3.3580)
z^*_{ijX}/z^*_{ijI}	-	-.000042	-	-.00177	-	.000143
	-	(.00078)	-	(.0012)	-	(.00171)
$(z^*_{ijX}/z^*_{ijI})^2$	-	-6.89e-08	-	-1.33e-07	-	1.92e-06
	-	(2.39e-07)	-	(6.30e-07)	-	(1.76e-06)
$(z^*_{ijX}/z^*_{ijI})^3$	-	-1.13e-10	-	3.52e-10	-	1.46e-10
	-	(1.90e-10)	-	(6.74e-10)	-	(2.05e-09)
R^2	.4253	.4330	.5302	.5380	.4703	.4737
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses: $*p < .10$, $**p < .05$, $***p < .01$

classification exists today. The results with enterprise heterogeneity controls thus substitute prior deviation from the model for inaccuracy arising from the differing units of measurement within the dependent variable since the export data refers only to specific industries whereas the FDI data remains as a measure of country sum totals. Even so, the estimations in Table 4 represent the full model and still help to cement the robustness of the pollution haven hypothesis because the coefficients on the environmental regulatory variable are again negative across all specifications. Once again, these results also indicate the existence of a global pollution haven effect in which enterprises are incentivized to locate where relative environmental standards are lower within each country pair.

The combination of the model of enterprise location decisions from Brainard (1993) and Helpman, Melitz, and Yeaple (2004) with the enterprise heterogeneity controls from Helpman, Melitz, and Rubenstein (2008) together provide a useful model estimation for measuring the impacts of bilateral variables on enterprise location decisions that data availability will hopefully be able to fully augment and improve in the future.

5. Conclusion

In the midst of a myriad of conflicting research findings on the topic in recent history, this paper has sought to establish a structured analysis of the pollution haven hypothesis by adopting a theoretical model describing where enterprises choose to locate their production. Through highlighting the role of country environmental standards in the enterprise production location tradeoff between exports and foreign direct investment, this study is able to discern the effect of relative country environmental standards on the locations of enterprise production. This paper contributes to the previous literature surrounding the PHH in multiple ways. Not only does this study develop a methodology that assesses the ratio of exports to FDI thus covering both production location possibilities and eliminating the bias from observing only one or the other, utilize an actual assessment of environmental regulations/enforcement rather than various proxies, and consider a large country sample that greatly expands the international coverage from previous research, but it also is the first analysis to recognize and account for the possible differential group effects between developed and developing countries as well as environmental standards by law and by enforcement – leading to the most important findings of this paper.

While the results illustrate the plausible existence of a systematic, global pollution haven effect – enterprises choosing to locate production where relative environmental standards are lowest – this effect is much more pronounced and highly statistically significant when the potential host country in each country pair is developing and environmental standards are measured in terms of the strictness of environmental regulatory enforcement. This finding is important within the broader contexts of international cooperation on environmentalism and sustainable development. If enterprises react adversely to greater environmental standards in developing countries – places where the incentives to attract industry are likely larger – it will be much more difficult to persuade these developing nations to adopt international environmental accords. Additionally, if enterprises respond to enforcement rather than letter of the law regulations, environmentalists could also potentially be fighting an upwards battle against an incentive for national governments to draw up strict environmental regulatory frameworks but never actually enforce them. Even so, in a more positive light, knowledge regarding the international economic effects of environmental standards will be able to better inform future environmental negotiations.

These results come with an important caveat, however. Defining export data in terms of all commodities precludes the ability to construct a direct control for enterprise heterogeneity, a central tenet of the model. On the other hand, segmenting the export data into separate industries encounters data availability issues because, as of yet, there does not exist any bilateral, industry-level FDI data for multiple countries. As a result, the complete model described in the methodology in equation (5) cannot yet be fully estimated. Additional econometric research could attempt to derive another control for enterprise heterogeneity that could be estimated even with the given data restrictions. An increase in the amount of countries reporting bilateral FDI data, or the addition of new, bilateral, industry-level FDI data, could also solve this problem for future research.

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Appendix

Table 1

Summary statistics for the two variables measuring country environmental standards

Variable	Mean	Standard Deviation	Minimum	***Maximum***
Environmental Regulation	4.5401	.9977	2.8	6.44
Environmental Enforcement	4.1684	1.0774	.662	6.38

Environmental Questions from Executive Opinion Survey

Environmental Regulation

“How would you assess the stringency of your country’s environmental regulations? [1 = very lax, among the worst in the world; 7 = among the world’s most stringent]”

Enforcement of Environmental Regulations

“In your country, how would you assess the enforcement of environmental regulations? [1 = very lax, among the worst in the world; 7 = among the world’s most rigorous]”

Figure 3

Histogram of the environmental stringency variable across the seventy included countries

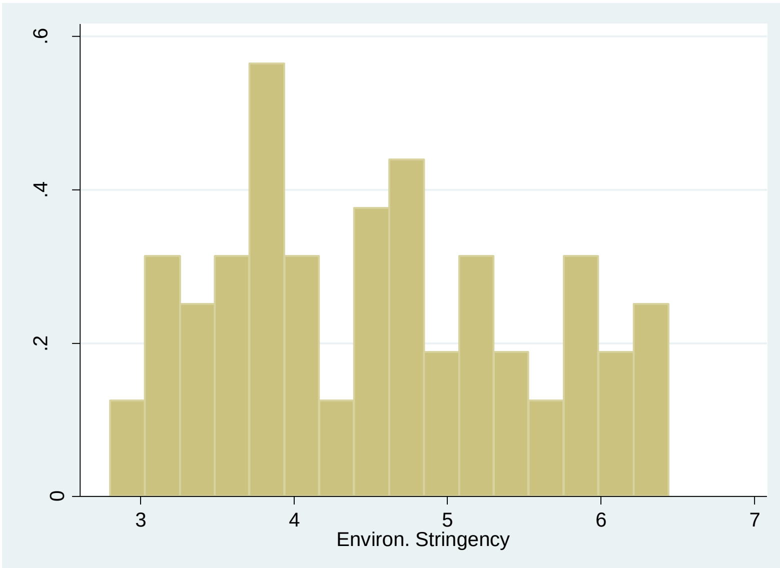

Figure 4

Histogram of the environmental enforcement variable across the seventy included countries